

## **SURFACE DAMAGES CAUSED BY CAVITATIONS AT HOOD OF HOWELL BUNGER VALVE AND REDESIGN TO AVOID THEM**

**DIMITRI KOZINAKOV, VALENTINO STOJKOVSKI & ZVONIMIR KOSTIKJ**

*University "Ss. Cyril and Methodius" Skopje, Macedonia, Faculty of Mechanical Engineering Skopje, Republic of Macedonia*

### **ABSTRACT**

*Howell Bunger valve is hydro mechanic equipment which obtains regulation of free water stream with very high flow velocity at small opening. High flow velocity rates are the main reason for the occurrence of cavitations in the area of hood and body of the valve. The practical data refer to occurred surface damages of this type of valves are very rare in the literature. In this paper, the Howell Bunger valve installed at the dam Lisice, R. Macedonia was analyzed. The analyzed valve was produced by CMO, Tolosa, Spain. After one year exploitation period, significant surface damages occurred on the hood as a result of cavitation. This condition of the valve was the reason for redesigning the critical zones of the hood with the aim to overcome the origin of cavitations for small opening of the valve. The technical solution for redesigning of the flow domain is developed by using CFD software FLUENT. On the base of numerical results, the technical solution was implemented at the valve. The proposed redesign of the hood is confirmed by seven years of exploitation period after implementation. The proposed reconstruction and results presented in this paper can be useful for the constructors and users of this type of valves, and can be implemented in the new design of the valves and also at old installed valves.*

**KEYWORDS:** *Howell Bunger valve, hood, cavitations surface damage*

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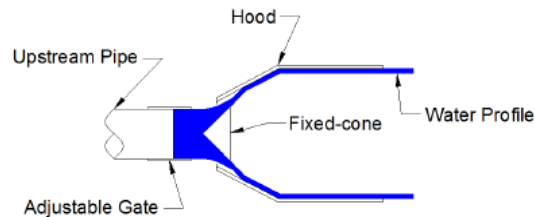
### **INTRODUCTION**

Fixed Cone Dispersion Valve (FCDV) was first developed and introduced for dam outlet works service in the early 1930's by Mr. Howell and Mr. Bunger. The original FCDV developed by Mr. C. H. Howell and Mr. Howard P. Bunger was acquired by the S. Morgan Smith Company in the mid 1930's and promptly trademarked as the Howell-Bunger® valve and remains as such today. The S. Morgan Smith Company was acquired by the Allis-Chalmers Corporation in the late 1950's and the Howell-Bunger® valve remained with the Allis-Chalmers Corporation until the late '80's when RHCO acquired it in the fall of 1990. This represents over seven decades of continuous history of FCDV and Discharge Hood applications covering a multitude of applications and installations [1]. FCDVs are used to control flow and dissipate energy under medium to high head conditions. The Howell-Bunger valve features a fixed cone and a mobile cylindrical gate, which slides forward to restrict the flow, or backward to increase the opening degree.

The valve forces the outflow into a diverging conical hollow jet, which produces a large area of energy dissipation through dispersion. The inflow is diverted by the cone, generating a hollow jet with significant radial deflection.

Depending on the installation, the conical jet may need to be controlled. There are two possibilities for installing a hood:

- A stationary hood can be placed over the conical jet as shown in Figure 1.
- Presence of a steel hood connected (installed) at the sliding part of the valve as shown in Figure 3. that effectively reduces the spray formation and limits lateral jet spreading within acceptable limits (Ring valve).



**Figure 1: Fixed Cone Dispersion Valve (FCDV) with Discharge Hood [2]**

The ring jet valve is endowed with a steel hood, which confines the lateral spreading of the air-water mixture. The inward deflection of jet streamlines enhances momentum exchange and gives rise to a contracted section observed at a distance of approximately 3 to 4 times the hood diameter. Beside these aspects, swirling motion has also been observed at the outlet.

Ring valves are rather poorly documented in literature, even less than Howell-Bunger valves. The behavior of the outgoing jet, the influence of the hood, the influence of aeration and in particular, the energy dissipation efficiency for a given upstream conditions and geometry require further investigation.

## CASE STUDY

Dam Lisiche - Veles, belongs to the system for the supply of drinking water (pipeline for cold water) and water for irrigation (pipeline for warm water). Both pipelines are used for bottom discharge of the lake. These two pipelines are installed along with the Howell Bunger valve to drain the water in riverbed Topolka. Technical characteristics of the dam are:

- maximum elevation: 452.12msl
- nominal elevation of water: 423 msl
- axis elevation of valve: 359.08 msl

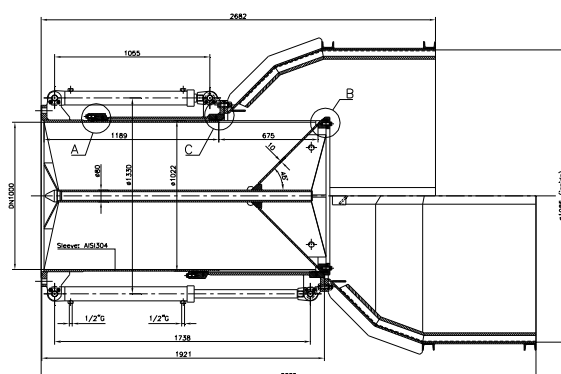


**Figure 2: Site Conditions**

## DESIGN OF VALVE

Construction of Howell Bunger valve consists of a cylindrical sliding segment, which is the carrier of the sealing flange A and C and the hood, and the static part of the valve which consists of a centrally placed tube. The movement of

valve (open/close) is achieved by hydraulic cylinder. In inner space of hood, are installed four cross-contrary aeration pipes.



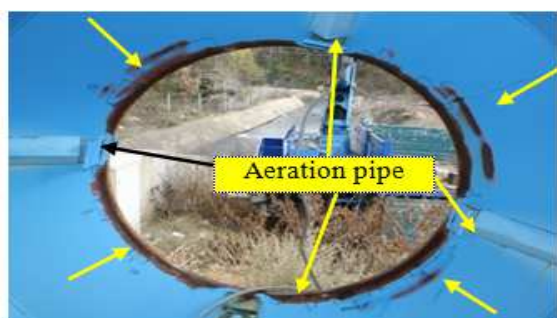
**Figure 3: Longitudinal Section of Valve with Sliding Hood**

Technical parameters of the valve are:

- maximum flow: 12.79 m<sup>3</sup>/s
- nominal flow: 2.04 m<sup>3</sup>/s
- nominal diameter of 1000 mm
- valve stroke: 675 mm
- nominal pressure: 10 bar
- operating pressure: 6.6 bar
- testing pressure: 13,3 bar

## SURFACE DAMAGE DUE TO CAVITATION

In the first year of exploitation, the need of continuous discharge of water through both valves (exploitation condition) was with flow rates of 0.5 to 3 m<sup>3</sup>/s (an average discharge of water is about 0.8 m<sup>3</sup>/s per valve). This means that the valve is open approximately 12-15 mm. After one year exploitation period, due to these exploitation conditions, significant surface damages caused by cavitations were detected on the hood. The main damages are located in the zone between aeration pipes fig.4. The cavitation damages occurred symmetrically around the surface between hood flange and hood cone.



**Figure 4: Zone of Cavitations Damages**



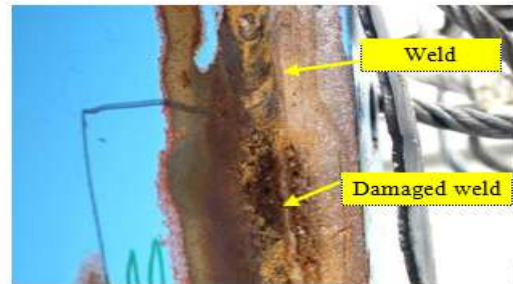
**Figure 5: Zone of Cavitations Surface Damages**

It is well known that cavitations can cause intensive removing of material particles at the surface, especially when the used material is constructional steel.

In this case, intensive cavitations process mainly occurred in the welded zone and the weld surroundings. Figure 5 thru Figure 7 shows zones affected by cavitations' surface damages process. Serious surface cavitation effects are shown on Figure 6 and Figure 7.



**Figure 6: Serious Surface Cavitations Damages**

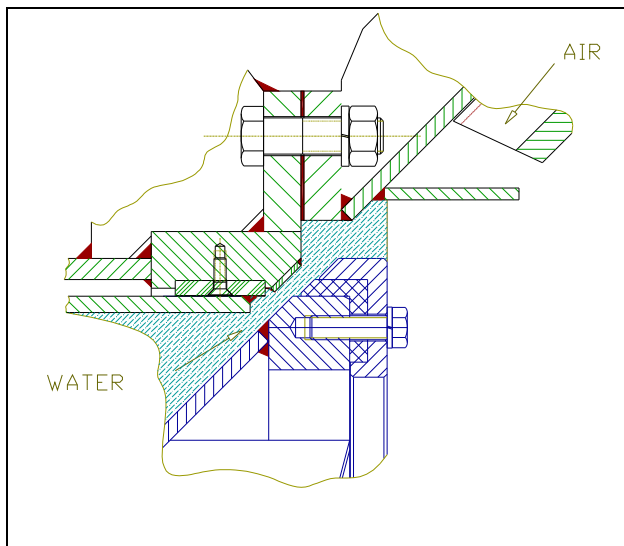


**Figure 7: Cavitations Damages in the Weld**

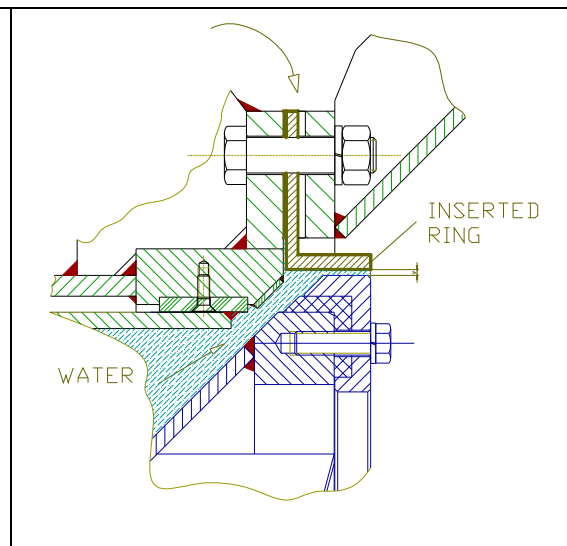
## REDESIGN OF HOOD

Because that the surface damages due to cavitations are unacceptable, redesign of the critical surfaces was necessary. Having in mind the fluid flow conditions, the geometry of the flow domain in low-opening position of the valve and possibilities for the origin of cavitation phenomena, the redesign of hood contains the following conceptual changes:

- The aeration system to be continual, not separated in the four main parts of the flow domain.
- The flow domain in case of low-opening of valve to form a continual decreasing of flow area, but after some opening of the valve the influence of flow to obtain unconditionally aeration in the local area.



**Figure 8: Flow Domains in Low-opening of Valve**



**Figure 9: Concept of Redesigned Hood**

The analyses of the flow domain in position of the small opening of the valve show that there are sections between hood and valve cone where flow velocity increases and the velocity decreases in the closed space which is not properly aerated (Fig.8). This configuration of flow domain is basic for potential obtaining cavitations phenomena. The cavitations damages which occurred at the valve hood confirm the same zone.

The basic concept of hood construction with aeration system and redesigned flow domain is shown on Fig.9. The installation of a ring provides change of the shape of the flow domain for low valve opening. The aeration of the space around the outlet jet is ensured by the full scale of the hood.

The redesigned aeration system is made on the flange of the hood by radial drilling one part and designed a channel. This model obtained continual aeration around the space of inner domain of hood where the velocity has effect of ejector. Preparation of redesigned aeration system is given on Figure 10.



**Figure 10: Redesigned Aeration System on Hood Flange**

The flow domain for low-opening is changed by inserting a cylindrical ring which obtained continual decrease of the flow area and to establish velocity dispersion in the free area.

## FIELD VERIFICATION

The proposed technical solution was field tested and following conditions were obtained:

- The numerically predicted effect of back splash was tested at site. The hood was installed with no changed of all its constructive elements. This case position is done only for confirmation of numerical prediction of back splash, and the effect of back splash was happening, Figure 11. The main reason for back splash was obstacle of elements of the basic aeration system of the hood which cannot obtain a free stream fluid flow.
- The internal elements of the aeration system were removed with the aim to obtain the free stream fluid flow and to reach the numerically predicted proper working conditions for redesigned hood (Figure 12).
- The influence of redesigned hood on dispersion of the outlet water jet was comparatively tested in case for obtaining the same openings - discharge (approximately  $0,5 \text{ m}^3/\text{s}$  or 10 mm opening) at reconstructed and basic design of the valve, Figure 13. For small openings of the valve the reconstructed hood has a uniformed outlet jet form and dissipation of energy is better than the basic model of the valve.





Figure 11: Effect of Back Splash at Redesigned Hood

Figure 12: Removing of the Original Aeration

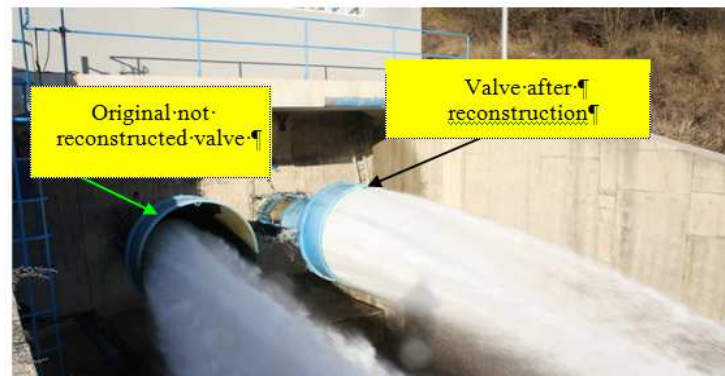


Figure 13: Redesigned Hood and Outlet Water Jet

### SURFACES CONDITIONS AFTER EXPLOITATION PERIOD

The reconstruction of redesigned valve was established in 2009 year. Working conditions of the redesigned valves after seven years (2009-2015) of exploitation period are represented through the discharge curve given on Figure 14.

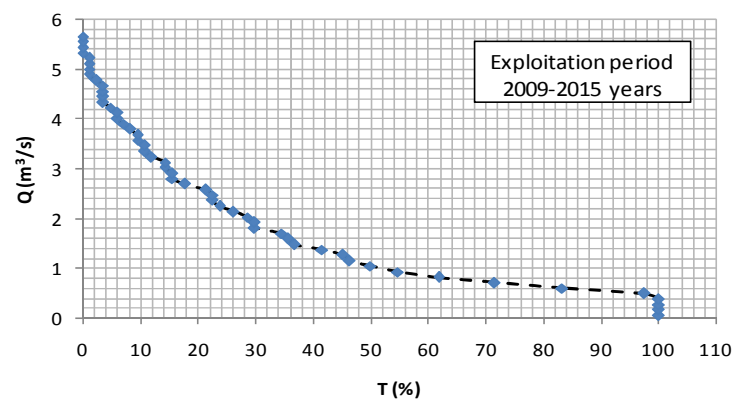


Figure 14: Flow Duration Curve for Exploitation Period of Seven Years

On the base of the flow duration curve can be seen that ~50% of exploitation conditions of the valve was happening for small openings of the valve. This means that main operating position of the valve is with a small opening section.

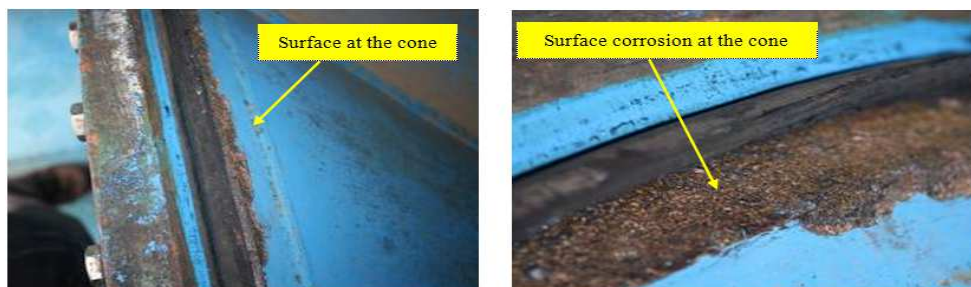
After this period of seven years, visual inspection on surfaces in the zone of water outlet section (surfaces of hood, surfaces of inserting ring and surfaces of the cone) was performed.

Visual control revealed another type of damage compared to the damage caused by the cavitation found in 2009. The new surface conditions are shown on the Figure 14 thru Figure 17.



(a) Upper Half-part of the Hood

(b). Lower Half-part of the Hood

**Figure 14: Surface of Hood in Closed Position (Front View)****Figure 15: Inner Surface of the Inserted Ring****Figure 16: Inner Cone Surface****Figure 17: Detail of Inner Cone Surface**

The results of the visual inspection of the surfaces show the following:

- After seven years of exploitation, no surface damage of the type of cavitation was detected.
- Certain surfaces are affected by corrosion, which is a normal occurrence for such equipment.
- The surfaces of the valve cone are affected by corrosion at the zone in front of the sealing ring.
- To deal with the occurrence of corrosion, an occasional recovery of anticorrosion protection, especially on surfaces near the sealing rubber ring, is required.
- No surface damage was detected on the inserted ring.
- The work of the redesigned hood is stable and no interference in the functionality of the valve has been observed.
- During the seven-year exploitation there was no need for repairs or servicing.
- This is sufficient proof that with the redesign and reconstruction of the bonnet the target has been achieved, ie the emergence of cavitation has been eliminated.

## CONCLUSIONS

The main goal of this paper is to contribute to a constructive improvement and elimination of cavitation phenomena through a redesign process. Cavitation causes intense destruction of the surface layer of the material of the Howell Bungler valve hood. The main reason for the occurrence of cavitation in the original design of the valve hood is the inadequately designed aeration system and the inadequate shape of the water outlet opening.

Damage to the surfaces of the material due to cavitation was evident within one year of releasing the valves into operation.

Comprehensive computer simulations and analyzes were made to solve the cavitation problem.

Finally, a redesign solution was adopted, which was successfully applied in the reconstruction of the outlet on the valves.

After the successful reconstruction, tests were performed in certain operating modes. It was done with parallel work and comparison between the original (old) and the newly designed solution of the hood of the valve.

The results of the tests showed that the redesigned valve hood works steadily in all modes of operation and especially during small openings of the outlet.

After seven years of exploitation, a control over the condition of the hood and valve surfaces was performed, and it was concluded that there was no occurrence of cavitation, which was the basic idea for a redesign.

The redesigned solution can be successfully applied to any construction of Howell Bunger valve with sliding hood.

The redesigned solution can be successfully applied to any construction of Howell Bunger valve with sliding hood. This solution successfully overcomes the problem of cavitation, especially when the valve works in a mode with small opening of the outlet.

## ACKNOWLEDGMENTS

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